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(54) System for acoustic caliper measurements

(57) In order to provide acoustic measurements downhole indicative of the reflectivity of the borehole 12 compensated for variations in the acoustic velocity of the drilling fluid, for example, an acoustic pulse 45 is transmitted from a first acoustic pulse transceiver 40 within the sidewall of a sub 14 forming part of the drill string and is reflected from the sidewall 20 of the borehole at a point 52. The reflected pulse 54 is detected both by the transceiver 40 and by a receiver 50 which is located within the sidewall of the sub 14 at a known axial distance d from the transceiver 40. The difference in the times of receipt of the reflected pulse 54 by the transceiver 40 and the receiver 50 is then used to determine the distance from the transceiver 40 to the point 52. A second acoustic pulse transceiver 42 may be provided within the sidewall of the sub 14 diametrically opposite the transceiver 40 for generating and receiving an acoustic pulse simultaneously with the transceiver 40, in order to compensate for non-coaxial position of the sub 14 and determine the diameter of the borehole.

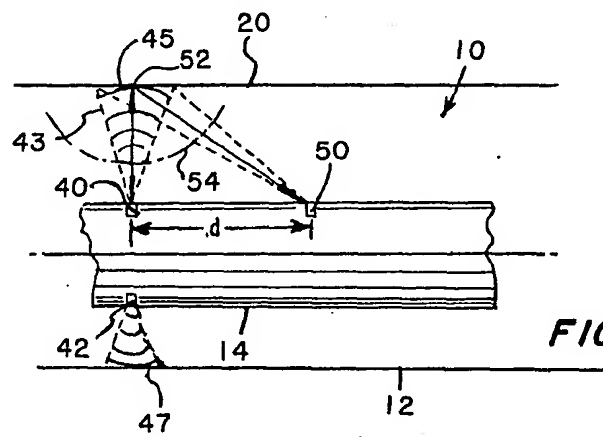

FIG. 3

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The drawing(s) originally filed was (were) informal and the print here reproduced is taken from a later filed formal copy.

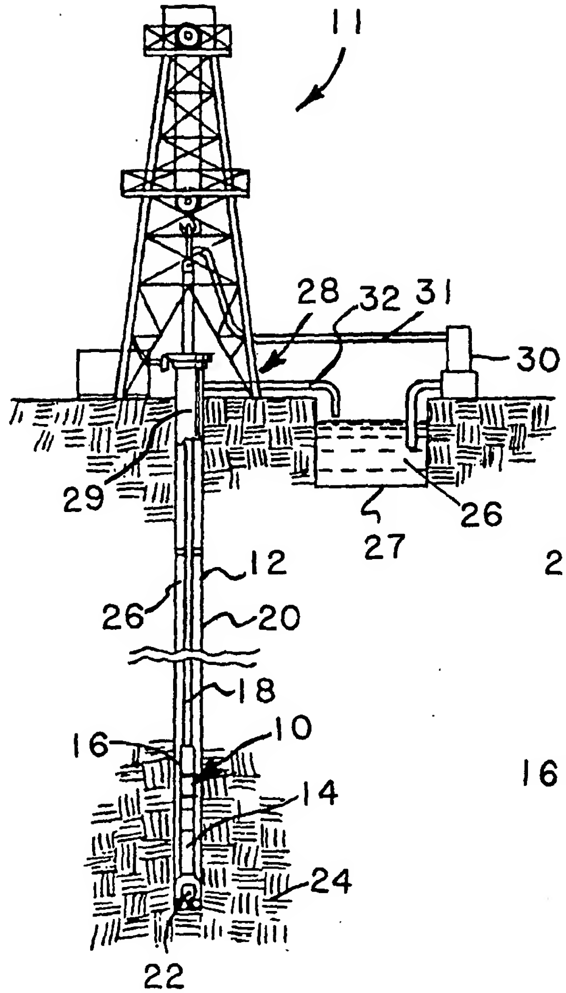

FIG. 1

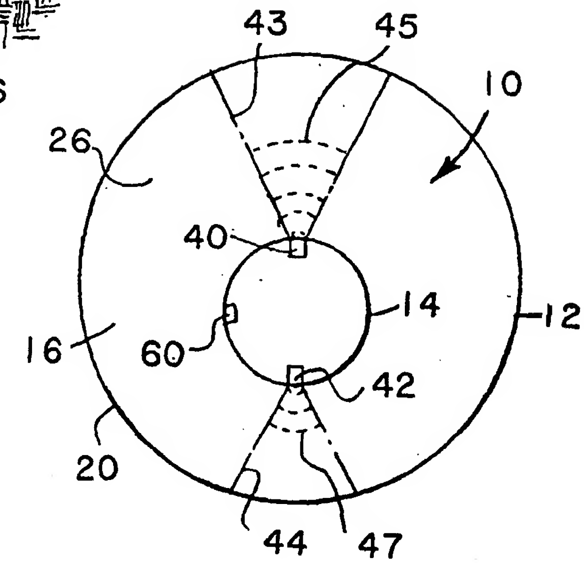

FIG. 2

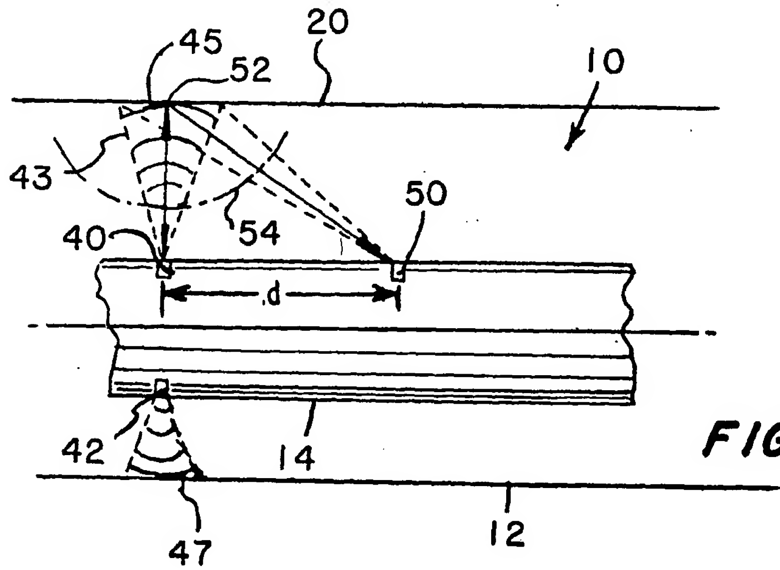

FIG. 3

SPECIFICATION

System for acoustic caliper measurements

The invention relates to an acoustic tool for measuring reflectively within a borehole and, more particularly, to a caliper instrument for use in a measuring while drilling environment utilizing acoustic pulses transmitted within a borehole.

It has long been recognized in the oil industry that the collection of downhole data during the drilling operation is of extreme value. Such information improves the efficiency of the drilling operation by providing critical data concerning downhole conditions. For example, it is desirable that a continuous record of borehole size be provided so that variations in borehole diameter as a function of depth may be recorded for analysis in connection with the operation of oil wells and the like.

Acoustic well logging is also used in the geophysical and seismic arts to provide surveys of the various formations traversed by the borehole. In particular, acoustic velocity measurements provide valuable information concerning the type of rocks and the porosity thereof in the formation surrounding the borehole. The most commonly measured acoustic parameter in the field of well logging has been the velocity of compression waves. The velocity of shear waves and acoustic impedance have also been of value in determination of both the formation characteristics and the fluid environment.

A myriad of acoustic logging systems for downhole measurements are available in the prior art. One of the most critical measurement parameters of such acoustic logging systems is the acoustic velocity in the fluid through which the acoustic pulse is transmitted. A high degree of resolution in the interpretation of pulse data is only possible with a precise knowledge of the acoustic velocity in the medium of measurement. Moreover, a high degree of resolution is necessary for the accurate identification of various formation strata as well as other critical borehole parameters.

Many prior art attempts to provide accurate acoustic logging instrumentation have encountered serious problems due to the downhole environment. For example, the drilling operation necessitates the flow of high pressure drilling mud which is pumped down through a central bore in the drill pipe, out through apertures in the drill bit and back to the surface through the annular space between the drill pipe and the side walls of the borehole. The mud removes drill bit cuttings and the like and ca reveal much information about the formation itself. Such a fluid sustem, by definition, includes wide variations in drilling mud density and character both along the borehole as well as in a direction across the borehole annulus. For example, gas present in the drilling fluid has a direct bearing on acoustic velocity within the fluid and the presence if gas varies with position and pressure within the borehole.

One prior art technique of determining acoustic velocity includes sampling the drilling mud at the wellhead for purposes of measurement. However, such a measurement cannot accurately reflect the varying conditions of the mud downhole where the acoustic measurements are actually made. Downhole acoustic pulse data is generally generated by acoustic transducers disposed within the side walls of a sub secured above an operating drill bit within the borehole. The acoustic pulses are transmitted from the sub to the sidewalls of the bore hole through the drilling fluid and the reflection time thereof is monitored. The presence of gas or cuttings within the fluid as well as downhole pressures and turbulence thus has a direct bearing on the acoustic velocity and the reflectivity measurements. However, the most convenient location for measuring acoustic velocity is at the wellhead in the passive fluid collection area where the dynamic turbulent downhole conditions are not present. In addition, once received from the borehole, the drilling mud is generally allowed to settle and/or is passed through an out-gassing unit prior to its collection and recirculation. This step drastically alters the acoustic velocity parameters of the drilling fluid from its downhole gaseous and turbulent condition and leads to inaccuracies in the interpretation of the downhole acoustic reflectivity measurements.

A prior art method of overcoming the problems of accurate data collection in a measuring-while-drilling environment is the recording of acoustic borehole measurements with a wireline logging tool. Such tools are utilised with the drill string removed from the borehole and the drilling mud being in a settled state. Such a condition lends itself to a more homogeneous configuration and the presence of mud cakes and turbulence related to non-homogeneous regions are generally eliminated. One such acoustic caliper logging device is set forth and shown in U.S. Patent No. 3,835,953 to Summers wherein a wireline tool is provided for positioning within a borehole. A transducer unit repeatedly generates an acoustic pulse as the transducer system is rotated to scan the walls of the borehole in a full circle. A scan of between 1 and 10 revolutions per second may be provided with the tool itself being generally centered within the borehole. The reflections of acoustic energy from the borehole wall are then from a small, centralised area whereby the system can be highly definitive of the character of the wall. Such information is obviously useful in an analysis of the borehole configuration. One distrinct disadvantage is, however, the necessity of pulling the drill string from the borehole for utilisation of the wireline tool. This operation is both time consuming and expensive from the standpoint of the drilling operation.

In addition, prior art wireline acoustic parameter measurement techniques have obtained acoustic velocity at a downhole location but the acoustic path over which the velocity measurements are made is different from the path over which the parameter is measured. For example, an acoustic caliper measurement made across a borehole annulus which relies on acoustic velocity data obtained in a direction parallel to the borehole axis will not be precise because of the nonlinearity of the flow pattern and flow densities across the borehole.

It would be an advantage, therfore, to overcome

the problems of the prior art by providing detailed acoustic caliper information of a borehole in a measuring while drilling configuration. This gives the driller immediate feedback as to the quality of the borehole being drilled and can be used to infer in situ stresses. The method and apparatus of the present invention provide such a system by utilising a series of acoustic transceivers disposed both laterally and longitudinally upon a drill string sub for use in a measurement while drilling mode. The acoustic transceivers further measure the drilling fluid acoustic velocity simultaneously with the measurement of distance, in the same location in the borehole as the desired distance measurement and along a portion of the same acoustic path as the distance measurement. This provides acoustic reflectivity data based upon an acoustic velocity measurement and a distance measurement generated with a common acoustic pulse. In this manner the accuracy of the data is much higher and more reliable than conventional prior art techniques.

The present invention relates to a method of and apparatus for making acoustic measurements within a borehole. More particularly, one aspect of the invention includes an acoustic caliper tool for use in a measuring while drilling environment within a borehole of the type utlising at least one acoustic transceiver disposed within a section of a drill string. The acoustic transceiver is adapted for generating an acoustic pulse and reflecting that pulse off the side wall of the borehole for determination of the period of time in which the acoustic pulse requires for return propagation. A second acoustic receiver is disposed longitudinally of the first transceiver a selected distance for receiving a portion of the acoustic pulse generated by the transceiver. The pulse sensed by the second receiver is determinative of the acoustic velocity of the borehole fluid through which the pulse has propagated since the distance between the second receiver and the transceiver is known.

In another aspect the invention includes apparatus for measuring reflectivity of the side walls of a borehole by transmitting a series of acoustic pulses and receiving acoustic energy reflected from the walls of the borehole in timed relation to pulse transmission which is dependent upon borehole diameter. The apparatus comprises a housing adapted for securement within a drill string for performing acoustic measurements in a measuring-while-drilling mode. Means are disposed within the housing for generating and receiving an acoustic pulse propagated toward and reflected from the side wall of the borehole. A second receiving means is lngitudinally disposed along the housing from the pulse generation means for receiving the acoustic pulse generated therefrom and reflected from the side wall of the borehole. Means are provided for processing the data produced by the receivers within the borehole along with means for transmitting the data to the wellhead. Comparison means are provided for comparing acoustic pulse travel time data to determine the difference in time between receipt of the transmitted acoustic pulse by the first and second receiving means. Distances within the well-bore as a function of the travel time of the acoustic energy are then calculated.

In another aspect, the invention includes the aforesaid measuring apparatus wherein the housing also includes an inclinometer disposed therein for producing data relative to borehole orientation. A second acoustic transceiver is also provided and disposed within the housing, and azimuthally spaced from the first, for generating and receiving an acoustic pulse simultaneously with the first transceiver means. Control means are incorporated to actuate the plurality of transceivers in a predetermined repetitive sequence. Another apsect of the invention includes means for producing the acoustic pulses at different selected frequencies and pulse widths.

In yet another apsect, the invention includes a method of measuring a distance within a borehole through the propagation of acoustic energy from a housing disposed as part of a drill string. The method comprises the steps of providing first acoustic pulse generating and receiving means disposed within the housing and providing second acoustic pulse receiving means longitudinally disposed from the first receiving means. An acoustic pulse is generated with the pulse generating means and reflected from the side wall of the borehole. A first portion of the acoustic pulse is received with the first receiving means, and a second portion of the acoustic pulse is received with the longitudinally disposed second receiving means. The time intevals for pulse propagation between the pulse generating means, the borehole wall and the first receiving means, on the one hand, and between the pulse generating means, the norehole wall and the second pulse receiving means on the other hand are measured. The distance between the pulse generating means and the borehole wall is determined as a function of the pulse propagation time intervals and distance between the first and second receiving means.

Brief description of the drawings

For a more complete understanding of the present invention and for further objects and advantages thereof, reference may now be had to the following description taken in conjunction with the accompanying drawings in which:

Figure 1 is a diagrammatic, side-elevational view of a borehole drilling operation illustrating the use of an acoustic caliper tool in accordance with the principles of the present invention;

Figure 2 is a top plan, schematic view, of the apparatus of the present invention illustrating a pair of acoustic transceivers reflecting acoustic pulses from the sidewalls of a borehole; and

Figure 3 is a side elevational, diagrammatic illustration of one embodiment of an acoustic caliper tool constructed in accordance with the principles of the present invention.

Detailed description of the preferred embodiment

Referring first to Figure 1, there is shown a drilling rig 11 disposed atop a borehole 12. A first embodiment of an acoustic caliper tool 10 constructed in

accordance with the principles of the present invention is carried by a sub 14 incorporated into a drill string 18 and disposed within the borehole 12. The system 10 is provided for the continuous measurement of acoustic velocity and distance within the annular region 16 defined between the sub 14 and the borehole sidewalls 20. A drill bit 22 is located at the lower end of the drill string 18 and carves a borehole 12 through the earth formations 24. Drilling mud 26 is pumped from a storage reservoir pit 27 near the well head 28, down an axial passageway through the drill string 18, out of apertures in the bit 22 and back to the surface through the annular region 16. Metal casing 29 is positioned in the borehole 12 above the drill bit 22 for maintaining the integrity of the upper portion of the borehole 12.

Still referring to Figure 1, the annulus 16 between the drill stem 18, sub 14 and the sidewealls 20 of the borehole 12 forms the return flowpath for the drilling mud. Mud is pumped from the storage pit 26 near the well head 28 by a pumping system 30. The mud travels through a mud supply line 31 which is coupled to a central passageway extending throughout the length of the drill string 18.Drilling mud is, in this manner, forced down the drill string 18 and exits into the borehole through apertures in the drill bit 22 for cooling and lubricating the drill bit and carrying the formation cuttings produced during drilling operation back to the surface. A fluid exhaust conduit 32 is connected from the annular passageway 16 at the well head for conducting the return mud flow from the norehole 12 to the mud pit 26 as shown in Figure 1. The drilling mud is typically handled and treated by various apparatus (not shown) such as out-gassing units and circulation tanks for maintaining a pre-selected mud viscosity and consistency. It may be seen that measurements of acoustic velocity of the drilling mud at or within the drilling pit 26 would thus be affected by the treated and stagnant condition of the mud.

The position of the acoustic caliper tool 10 upon the drill sub 14 relative to the borehole walls 20 will vary during rotation. The drill string 18 may be rotated for imparting the requisite cutting action to the drill bit 22 and, during rotation, the drill string 18 often rubs against the walls of the borehole 12. Such rubbing results in mis-alignments and the non-centralized positioning of the acoustic caliper tool 10 relative to the borehole walls 20. The measurement of distances with the tool 10 by means of acoustic pulses which are reflected from the borehole walls 20 must therefore be extremely precise in order to produce data which accurately depicts the dimensions and shape of the borehole. This precision of measurement must also be maintained in view of the presence of gas, formation cuttings, and non-homogeneous fluid flow conditions as is typical in most drilling operations. Moreover, dimensions of non-uniform borehole cross-sections must be measured as well as the variations in acoustic reflectivity which are indicative of different formation materials.

The method and apparatus of the present invention provide a system capable of producing data of an accurate and reliable nature indicative of borehole shape and size by utilizing a common acoustic pulse for both the determination of acoustic velocity within the turbulent flow of non-homogeneous drilling fluid in the borehole annulus as well as the distance between the sub 10 and the borehole wall 20. In this manner, all distance measurements will utilize the actual acoustic velocity of the fluid medium through which the distance measurements are made.

Referring now to Figure 2, there is shown an enlarged, top plan schematic view of one embodiment of the acoustic caliper 10 constructed in accordance with the principles of the present invention. The tool 10 comprises first and second transceivers 40 and 42 disposed within the sidewalls of the sub 14. As used herein an acoustic transceiver comprises a single acoustic transmitter and a single acoustic receiver generally constructed in the same device. Focused acoustic energy radiation patterns 43 and 44 are illustrated propagating from the acoustic transceivers 40 and 42, respectively. An acoustic pulse 45 is thus shown propagating from transceiver 40 within radiation pattern 43. An acoustic pulse 47 is likewise shown propagating within radiation pattern 44 from transceiver 42. The acoustic pulses 45 and 47 are directed toward the sidewalls of the borehole 20 and are reflected therefrom back to the transceivers 40 and 42 where they are detected by the receiving means incorporated into each transceiver. The travel time which the acoustic pulses 45 and 47 require for reflection and return to transceivers 40 and 42,, respectively, is a determination of the distance between the transceivers and the borehole wall. However, an interpretation of acoustic pulse travel time delay data requires a determination of the acoustic velocity of the drilling fluid 26 disposed within the annulus 16 of the borehole 12. Due to non-homogeneous nature of the fluid flow pattern as well as the presence of gas and earth cuttings in the fluid, the acoustic velocity through the fluid will vary with time as well as distance. Thus, the required time for propagation and return of acoustic pulses 45 and 47 will also vary. By also utilizing the same acoustic pulses 45 and 47 to determine both distance measurements as well as acoustic velocity of the fluid medium 26 through which the distance measurement is made, the distance determination will be both inherently accurate and reliable. Moreover, the data produced during the measurement process will also be an accurate indication of drilling mud conditions at the location of acoustic caliper measurement.

Referring now to Figure 3, there is shown an enlarged side elevational, schematic view of the acoustic caliper tool 10 constructed in accordance with the principles of the present invention. Transceivers 40 and 42 are shown secured to the sub 14 along a common azimuthal plane. A third acoustic device 50 is shown secured to the sub 14 and disposed longitudinally relative to transceiver 40 as known selected distance "d". The acoustic device 50 may be either a transceiver or simply a second acoustic receiver for sensing the reception of acoustic pulses 45 propagated from the transceiver 40.

Still referring to Figure 3, it may be seen that an acoustic pulse 45 propagated from transceiver 40

will engage the side wall 20 of the borehole 12 and be reflected therefrom for direction by both the first receiver forming part of the transceiver 40 and to the second receiver 50.The radiation pattern 43 of acoustic pulse 45 is thus schematically shown with the pulse contacting the side wall of the borehole 30 at a point 52. The pulse 45 is thereafter reflected back toward transceiver 50 as a reflection pulse 54. Because the distance between transceiver 40 reflection point 52 is less than the distance between the second receiver 50 and point 52 the pulse 54 will arrive at transceiver 40 first. The difference between the time when the pulse 54 to arrives at the first receiver of transceiver 40 and when the pulse 54 arrives at the second receiver 50 is determinative of the distance between the transceiver 40 and point 52 on the borehole wall. The distance becomes a geometric function since the distance between the transceiver 40 and the receiver 50 is known.

Referring still to Figure 3, it may be seen that the distance between transceiver 40 and receiver 50 is a design parameter. Optimal distance will, of course, be a function of the geometries involved in the measurement. Utilization of conventionl geometric formulation relative to the distances and times involved and the application of differential equations will permit maximization of the desired resolution. The distance between transducer 40 and receiver 50 is thus selected to obtain resolutions which are both useful and feasible considering downhole conditions.

The present invention contemplates the use of a single transmitter and first receiver 40 and a second receiver 50 longitudinally disposed therefrom. In order to compensate for non co-axial positioning of the tool within the borehole and. or whipping of the drill string 18 which is common during a drilling operation, a plurality of transceivers 40 and 42 are preferable. In such a configuration, both the transceivers would be pulsed simultaneously while only one would be needed to measure an acoustic velocity in conjunction with a second receiver 50. However, if desired each transceiver 40 and 42 could be coupled to an associated second receiver 50 longitudinally spaced therefrom for its own calibration to allow for acoustic velocity variations in the borehole fluid transmission media at different azimuthal positions in the borehole annulus. Such a configuration would account for non-homogeneous mud flow which could cause errors in the distance measurements. In essence, the use of a single acoustic wave 45 for both measuring distance and acoustic velocity is a distinct advantage which may be preferable for any transceiver array.

In operation, the acoustic transceivers 40 and 42 are disposed upon a drill collar or downhole sub 14 with a longitudinally disposed reference receiver 50 for in situ measurement of the acoustic velocity of the drilling mud 26 within the annulus 16 of the borehole 12. In situ measurement utilizing a common acoustic pulse 45 is inherently more accurate than pulse systems using separate pulses for acoustic velocity determination and distance determination within the borehole. Such an operation is only possible with a transducer configuration adapted for withstanding the vibrations encountered during downhole drilling operations and of a configuration which will reduce the effects of reflections from cuttings in the drilling mud. For this reason, the azimuthally disposed transceivers 40 and 42 and longitudinally disposed reference receiver 50 are preferably recessed within the sub 14 to provide a smooth outer wall as shown in Figures 2 and 3. The transducers may also be mounted in the drill collar in select configurations for reducing "ringing" of the acoustic waves within the drill collar. A shaped transducer configuration has been shown to reduce these internal reflections.

It may be seen from the above that in situ caliper measurements utilizing the system 10 of the present invention necessitates only time interval measurements. Generally azimuthally spaced measurements may be averaged to obtain an average diameter of the borehole 12 when a single transducer 40 is utilized in conjunction with a receiver 50. A dual or triple transducer array will, of course, give much more accurate and readily utilizable sizing of the borehole 12 in situations where the sub 14 is not coaxial within the borehole.

Multiple transducer arrays are of particular concern during acoustical investigation of the subleties of borehole wall construction wherein the acoustic energy reflected from the formation along the side walls of the borehole 20 depends upon the acoustic impedance and surface characteristics of the formation. Surface roughness and impedance mismatch, as well as formation chips and formation surface characteristics will attenuate the acoustic pulse although the time frame will remain constant. The attenuation affects in the acoustic pulse thus represents the reflectivity of the surface from which the pulse is reflected. By utilizing an angle or azimuthal position sensor 60 as schematically represented in Figure 2, the reflectivity data may be further refined to define one period of rotational data for purposes of analysis. The data collected from a second period of rotation may then be collected and stored in the memory of a mcroprocessor system (not shown) for subsequent processing. In this manner, one set of borehole data may be processed while a second set of data is being taken during another rotational cycle.

It has thus been shown that a transceiver array capable of high resolution will be effective in producing not only a clear picture of borehole configuration but other downhole parameters as well. Because of the rotation of the drill string 18 repetitive data will be produced indicative of changes in the borehole but also capable of monitoring parameters defining the flow of drilling mud 26 within the annulus 16. For example, the presence of gas and earth cuttings within the drilling fluid 26 will have obvious effects upon the reflectivity of the fluid which may be determined by an appropriate filtering system. In the same manner the roughness of the borehole may likewise be determined by measuring the degree of reflection at the same time an in situ measurement of velocity is completed.

The method and apparatus of the present invention will also provide MWD data about actual

formation properties within the borehole in addition to that discussed above. By utilizing relatively high frequencies (1 to 3 MHz) of acoustic pulses an operator can filter out the relatively low frequency mechanical noises generally encountered during a drilling operation. Pulsing the array at different frequencies will also provide additional data and inherent filtering. For example, utilizing different pulse widths and pulse rates can provide surface roughness information because roughness reflections depend upon the size of the roughness particles relative to wave lengths and therefore the use of different frequencies provides more accurate data.

It is thus believed that the operation and construction of the present invention will be apparent from the foregoing description. While the method and apparatus shown and described has been characterized as being preferred, it will be obvious that various changes and modifications may be made therein without departing from the spirit and scope of the invention as defined in the following claims.

CLAIMS

1. Apparatus for measuring the reflectivity of the side walls of a borehole by transmitting a series of acoustic pulses and receiving acoustic energy reflected from the walls of the borehole in timed relation to pulse transmission, said apparatus comprising:

a housing adapted for securement within a drill string for performing said measurement in a measuring while drilling mode;

a first acoustic pulse transceiver disposed within said housing for generating and receiving an acoustic pulse propagated toward and reflected from the side wall of said borehole;

means longitudinally spaced along said housing a known distance from said first transceiver for receiving said acoustic pulse generated therefrom and reflected from the side wall of said borehole;

comparison means for determining the difference in time between receipt of said acoustic pulse by said first transceiver and said receiver; and

means for calculating the distance from said first transceiver to the borehole wall from said difference in travel time and said known distance

2. The apparatus as set forth in claim 1, wherein said housing includes an inclinometer disposed therein for producing date relative to borehole orientation.

3. The apparatus as set forth in claim 1 and further including a second acoustic transceiver disposed within said housing and azimuthally disposed therefrom for generating and receiving an acoustic pulse simultaneously with said first transceiver.

4. The apparatus as set forth in claim 3 and further including control means to actuate said plurality of transceivers in a predetermined respective sequence.

5. The apparatus as set forth in claim 1 and further including means for producing said acoustic pulses at selected frequencies and pulse widths, to obtain data relative to a common area of said borehole with acoustic energy having different characteristics.

6. The apparatus as set forth in claim 1, wherein a plurality of acoustic transceivers are mounted within said housing in a configuration azimuthally disposed one from the other and a plurality of respectively asociated receivers are spaced longitudinally from said transceivers for simultaneously providing data as to the travel time of an acoustic pulse generated and received by each of said transceivers relative to receipt of said reflected pulse by each associated longitudinally spaced receiver.

7. A method of measuring a distance within a borehole through the propagation of acoustic energy from a measurement device housed within a drill string suspended within the borehole, comprising the steps of:

providing a first acoustic pulse transmitter disposed within said housing;

providing a first acoustic pulse receiver adjacent said first transmitter within said housing;

providing a second acoustic pulse receiver within said housing and spaced longitudinally from said first receiver a known distance;

generating an acoustic pulse with said first transmitter; and permitting said pulse to propagate outwardly therefrom;

reflecting said acoustic pulse from the side wall of said borehole;

receiving a first portion of said acoustic pulse with said first acoustic pulse receiver;

receiving a second portion of said acoustic pulse with said longitudinally spaced second acoustic pulse receiver;

measuring the time interval for pulse propagation between said transmitter, said borehole wall and said first acoustic pulse receiver and between said transmitter said borehole wall and said second acoustic pulse receiver; and

determining distances within said borehole along said acoustic path as a function of said measured time intervals and the known distance between said first acoustic pulse receiver and said second acoustic pulse receiver.

8. The method as set forth in claim 7 and also including the steps of providing an inclinometer disposed within said housing and producing data therefrom relative to borehole orientation

9. The method as set forth in claim 7 and further including the steps of providing a second pulse transmitter and an adjacent receiver within said housing azimuthally disposed from said first transmitter and adjacent receiver and generating and receiving acoustic pulses simultaneously with said first transmitter and receiver.

10. The method as set forth in claim 9 and further including the step of providing control means to actuate said plurality of transmitter and adjacent receiver pairs in a predetermined repetitive sequence.

11. The method as set forth in claim 7 and further including the step of producing said acoustic pulses at selected frequencies and pulse widths and to obtain data relative to a common area of said borehole with acoustic energy having different characteristics.

12. The method as set forth in claim 7 and including the step of mounting a plurality of acousitc transceivers within said housing in a configuration azimuthally disposed one from the other, the step of mounting a plurality of receivers longitudinally disposed from said transceivers, and the step of simultaneously generating data as to the travel time of an acoustic pulse generated by said transceiver relative to receipt of said reflected pulse by said transceiver and by said longitudinally disposed receiver.

13. An improved method of measuring the geometry of a borehole by reflecting acoustic pulses off of the side wall thereof and measuring the time of flight of said pulses, wherein the improvement comprises providing a housing adapted for securement within a drill string for positioning within said borehole in a measuring while drilling mode;

providing a first acoustic pulse transceiver within said housing adapted for generating and receiving acoustic pulses therefrom;

providing an acoustic pulse receiver within said housing and spaced longitudinally from said acoustic transceiver a known distance and adapted for sensing the reflection of an acoustic pulse transmitted by said transceiver;

generating an acoustic pulse with said transceiver; and permitting said pulse to propagate outwardly therefrom;

reflecting said acoustic pulse off a side wall of said borehole;

receiving said acoustic pulse with said transceiver and recording the time of flight thereof;

receiving said reflected acoustic pulse with said acoustic receiver and recording the time of flight thereof; and

determining the distance of said acoustic path of said transceiver pulse as a function of said recorded times of flight and the known distance between said transceiver and receiver.

14. The method as set forth in claim 13 and further including the step of providing a second transceiver azimuthally disposed from said first transceiver for simultaneously generating an acoustic pulse therewith.

15. Apparatus for measuring the reflectivity of the sidewalls of a borehole, the apparatus being substantially as hereinbefore defined with reference to the accompanying drawing.

16. A method of measuring a distance within a borehole, the method being substantially as hereinbefore defined with reference to the accompanying drawing.

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